In : Lee, Jeffrey A. and Zobeck, Ted M., 2002, Proceedings of ICAR5/GCTE-SEN Joint Conference, International Center for Arid and Semiarid Lands Studies, Texas Tech University, Lubbock, Texas, USA Publication 02-2 p. 352

High-resolution stable isotope geochemistry of aeolian dust from Owens Lake, California

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Introduction

Geochemical characteristics such as trace element and isotopic compositions have been used to trace the transport of mineral dust to its source. An inherent assumption in such studies is that geochemical signatures are preserved during dust formation and aeolian transport. Here we test this premise by examining the stable isotopic ratios of carbonate in dusts from Owens (dry) Lake, California, a large desiccated playa subject to wind erosion of unconsolidated surface sediments. The dust emissions from Owens Lake have been the subject of many papers presented at previous International Conferences on Aeolian Research (e.g. Gillette *et al*., 1996: Niemeyer *et al*., 1999)

Materials and Methods

In the Lake Owens Dust Experiment (LODE) of 1993, aeolian sediments were captured in BSNE samplers (Fryrear, 1986) during their generation at 6 heights above the playa surface in seven sites along a one-kilometer linear transect parallel to prevailing winds during three dust events over a two-week period (Gillette *et al*., 1996), as the lakebed evolved from an evaporite-covered to a clastic-covered surface (Cahill *et al.*, 1996). For four selected sites up to five heights (10, 20, 50, 60, 100 cm) were measured for isotopic composition. Approximately one hundred dust samples, free of organic C, were digested in phosphoric acid and the CO_2 produced from carbonates at 25.2°C was analyzed for C and O stable isotopes. Isotopic compositions were determined on a VG-SIRA 12 gas-source ratio mass spectrometer equipped with a micro-inlet system. Results are reported using the conventional □ notation using V-PDB as the international standard and are in ‰ units. The acid fractionation factor for calcite (1.01025) was assumed in calculating the □^{18}O value of the carbonate. Precision of analysis is generally better than 0.1‰.

Results and Discussion

The overall variation in delta values among the samples is –0.5 to +4 and –5.5 to –2.5 ‰ for □^{13}C and □^{18}O, respectively. The relatively high □^{18}O values are consistent with hydrologically closed system conditions (evaporation) for the carbonate generation.

Both isotope systems show variations with sampling height, collection site, and time. The first major dust storm of the season (3/11- N wind) produced carbonates with the lowest $\delta^{18}O$ and $\delta^{13}C$ values and generally the most extreme decrease in these heavy isotope values with height at the four sites studied. The dust showed progressively higher $\delta^{18}O$ and $\delta^{13}C$ downwind with a constant shift of nearly 2‰ independent of height. The second storm (3/17- S wind) showed a decrease in $\delta^{18}O$ and $\delta^{13}C$ with increasing height above the playa surface at each locality, though less pronounced than in the first event. There is less variation between sites (1‰) than the first storm but the order of enrichment among the sites is still the same. The third storm (3/23- S wind) produced the smallest variation with height at each site and the smallest variation between sites (0.5‰). Overall, there is a linear relationship between C and O isotopes for the carbonates in Owens Lake dust (Figure 1), and their $\delta^{18}O$ and $\delta^{13}C$ values increased (i.e. the windborne sediments became more enriched in the heavier isotopes of both elements) (Figure 2) with each successive dust emission event after the initial erosion of the efflorescent crust (Cahill *et al*., 1996).

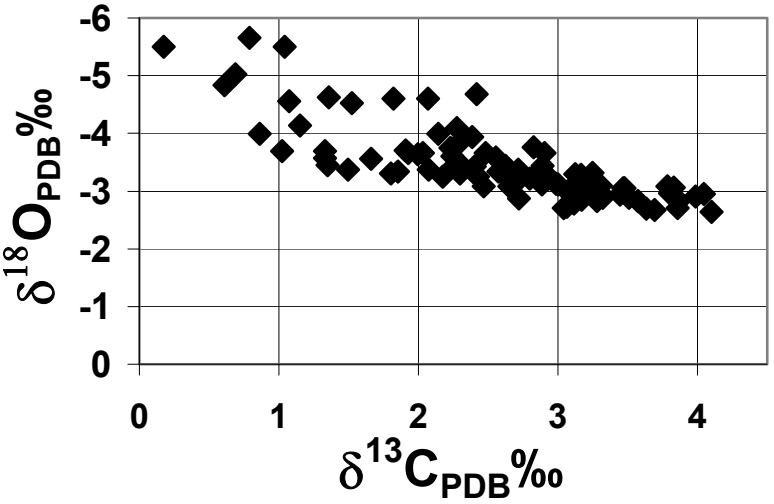

Figure 1. All stable isotope data points for Owens Lake carbonate samples analyzed in this study.

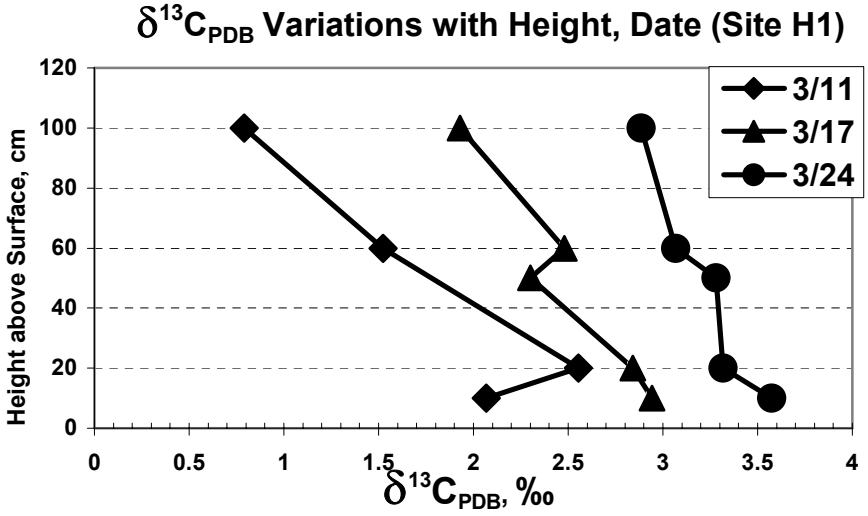

Figure 2. Example site data shows isotopic decrease with height, increase with sequential events.

There are several possible sources of the dust carbonate. To the north of the sampling transect on Owens (dry) Lake was located a large salt pan and to the south, sand dunes. These, however, do not appear to have contributed significant carbonate dust to the collectors during the storms nor varied along the sampling transect since the isotopic enrichment did not appear to depend on wind direction.

A more likely source of the carbonate is the lakebed sediment itself. During the flooding of pluvial Lake Owens, detrital carbonate was brought in and subsequently during evaporation authigenic carbonates have formed. The change in the isotopic composition of the carbonates in Owens Lake dust over successive emission events in both horizontal and vertical directions appears to reflect a change in the dust source materials exposed on the playa from authigenic (evaporitic) type to a more clastic type consistent with the physical changes to the wind-exposed playa surface observed during the sequence of dust storms by the LODE researchers. The isotopic composition of the dust could thus be considered a mixture between these sources, reflecting the quickly-changing chemistry of the lakebed sediments exposed to the wind.

It is also possible that wicking of the groundwater is redepositing a thin new layer of evaporite minerals between each dust event (Saint-Amand *et al.*, 1986). These new minerals might differ slightly in their isotopic composition from pre-existing playa materials due to subtle variations in conditions of deposition, accounting for the slight shift between the storms. The dust collected during the first event represents a large set of efflorescent evaporites that accumulated during the previous winter. The particles from the subsequent dust storms may contain newly formed sets of evaporites deposited on the playa surface between the individual storms. The emplacement of new material between dust events could account for the increase in $\delta^{18}O$ and $\delta^{13}C$ values.

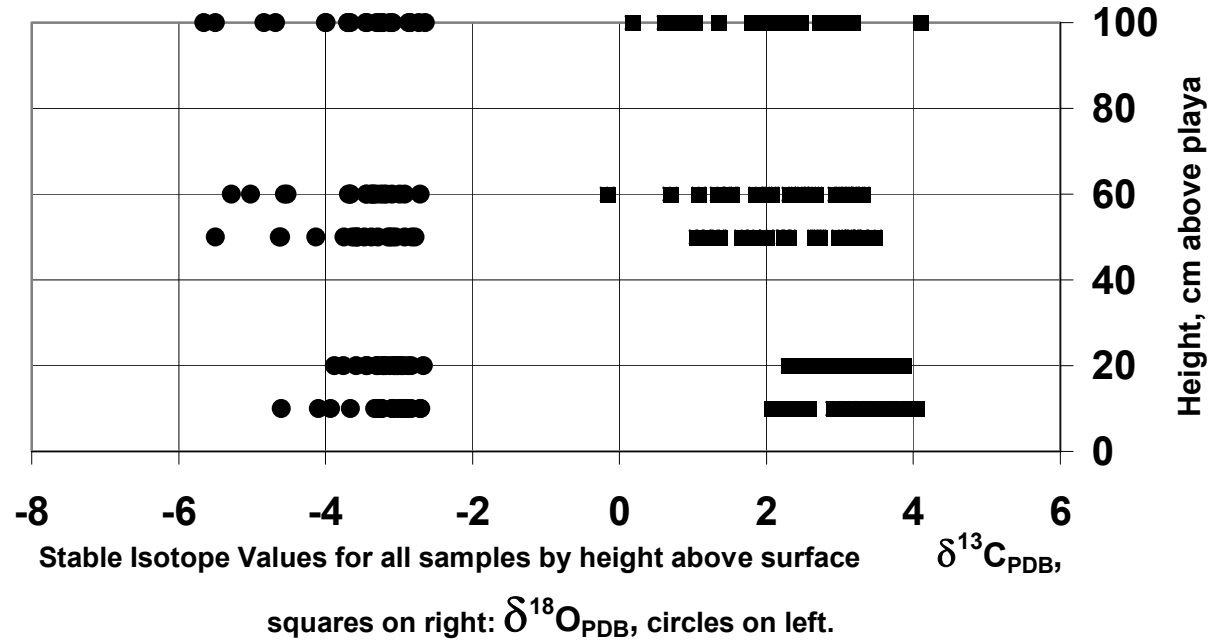

Figure 3. Stable isotope data, all samples: saltation zone 10- 20 cm, suspension zone 50- 100 cm.

There appears to be a distinct isotopic difference between saltation and suspension layers in these samples (Figure 3). Fryrear and Saleh (1993) described sedimentological differences between such distinct layers immediately above the soil surface during wind erosion, with the

"transition" below which saltation dominates and above which suspension dominates generally at a height of 30 to 50 cm above the soil surface. Gillette *et al*. (1997) demonstrated that such an effect was well-defined for this set of Owens Lake samples; it is also well-indicated in the stable isotope analyses shown in Figure 3. The saltation-dominated particles collected at 10 and 20 cm above the surface have a more homogeneous isotopic signature. This signature ranges from approximately +2 to +4 and –4.5 to –2.5‰ for $\delta^{13}C$ and $\delta^{18}O$ respectively for all three storms, or a 2‰ positive shift. The 20 cm samples are slightly more homogeneous than the 10 cm samples. The suspension-dominated particles from the 50, 60, and 100 cm heights are much more heterogeneous, including more negative values for both carbon and oxygen. The ranges are –0.5 to +4 and –5.5 to –2.5‰ for $\delta^{13}C$ and $\delta^{18}O$ respectively for all three storms.

Conclusions and Further Plans

Our study suggests that it may be possible to trace the origins of aeolian dust to its source using stable isotopes in carbonates as long as the individual sources differ by at least several ‰ from each other. There does appear to be an intrinsic isotopic difference between the suspension and saltation components of wind-eroded material. This research indicates that wind-eroded dust becomes more varied in isotopic composition with increase in height above the soil surface, representing mixing of aerosols from a larger source area. Saltating grains near the surface represent a much smaller source area and may not give an accurate sample of the overall lakebed geochemistry and sedimentology. Thus, care must be taken when comparing the geochemistry of aeolian dusts to that of potential source sediments. We will be using X-ray diffraction and trace-element analysis data next to investigate if the saltation and suspension layers also differ significantly in chemistry and mineralogy.

Acknowledgment: This work is supported in part with funding from the Texas Higher Education Coordinating Board Advanced Research Projects (ARP) Grant 003644-0327-1999. We thank Dale Gillette and Trevor Ley for collecting the samples, often under adverse field conditions.

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